

Leaf and culm sheath morphology of some important bamboo species of Assam

K. K. SARMA and K. C. PATHAK*

Rain Forest Research Institute, Jorhat, P. B. No. 136, Jorhat 785 001, Assam, India

Abstract—Eight species of bamboo, i.e. *Bambusa nutans*, *B. tulda*, *B. balcooa*, *B. bambos*, *B. pallida*, *Melocanna baccifera*, *Dendrocalamus hamiltonii* and *D. giganteus*, were studied for their leaf and culm sheath morphology with a view to make use of these characters in the field identification of these bamboos. The study revealed that both the plant parts are equally useful in field identification of the bamboo species studied so far. Keys to the species based on the characters studied have been formulated.

Key words: Bamboo; leaf; culm sheath; morphology; identification; key.

INTRODUCTION

Bamboos are long-lived, evergreen plants, belonging to the family Poaceae. The taxonomy of bamboo is most controversial, as they flower once in 30 to 100 years. As the orthodox system of classification is based on the reproductive structures, the early botanists were compelled to depend on herbarium specimens for taxonomic studies of bamboos. Furthermore, the flower structure of bamboo, as in other members of the Poaceae are so reduced that it needs specialized methods of observation such as using compound microscope and studying microtome sections. These two factors, i.e. non-availability of flowers as and when required and the reduced size of flower led to considerable confusion regarding classification and nomenclature of bamboos.

Therefore, it is important to find out some important vegetative characters, as well as formulating keys for easy identification of locally available bamboos. Eight species were selected for this study, carried out in a programme by Rain Forest Research Institute, Jorhat.

*To whom correspondence should be addressed. E-mail: rainfor@sancharnet.in

The present communication is based on detailed morphological characters of leaf and culm sheath of eight species namely *Bambusa nutans*, *B. tulda*, *B. balcooa*, *B. bambos*, *B. pallida*, *Melocanna baccifera*, *Dendrocalamus hamiltonii* and *D. giganteus*.

MATERIALS AND METHODS

The plant parts under study (i.e. leaf and culm sheath) were collected from the germplasm bank of Bamboo of Rain Forest Research Institute, Jorhat. Fully mature green leaves were collected from at least two years old culm while the culm sheaths were collected from the same node (fifth node) of fully-grown current year culm from each species. Both the plant parts were studied under stereoscope and their characters were recorded.

OBSERVATIONS

Detailed leaf and culm sheath characters of the species are as follows:

Bambusa nutans Wall. ex Munro

Assamese name Mokal Bah.

A medium-sized bamboo. At maturity, culms up to 22 m high, 27 cm in diameter, internode up to 39 cm long. The number of culms in a clump is up to 75.

Leaf: usually 6 leaves in each branchlet, rarely 7 or more, 15–20 cm long and 2.3–3.5 cm wide at middle, oblong-elliptic in early stage but obovate-oblong at maturity, base truncate to subcordate, apex acuminate, margin scabrous, 5–8 secondary veins in both side of midvein, adaxial surface with shiny long silky hairs, particularly on the vein, glaucous green with distinct yellow midvein up to middle, abaxial surface whitish green, puberulous with finely soft silky hairs. Leaf sheath light yellowish green, pilose. Petiole short, *ca.* 2 mm long. Auricle falcate (extended) with few long bristles. Ligule short, yellowish, 1–1.5 mm long, upper margin more or less straight. Leaf sheath light yellowish green, pilose. In cross-section, the stem is oval-shaped (Fig. 1, panel 1).

Culm sheath: wide triangular with pointed tip, 18–20 cm long and 20–24 cm wide at base, adaxial surface glabrous or sparsely glandular hairy, abaxial surface provided with dense appressed dark brown hairs in two sides but not in middle, abaxial surface of sheath base with thick woolly black or brown hairs. Sheath tip wide, obtuse or rounded, margin glabrous, hyaline and filmy. Median region obtuse or round. Ligule 1.5–2 mm, coriaceous, margin more or less in equal position, median region gradually upwards, smooth, round. Auricles 2, attached to ligule, unequal, one longer than the other and with long bristles, both auricles having wrinkles. Blade wide triangular with pointed acute tip. In the adaxial surface of blade, long black or brown hairs seen in stripes, abaxial surface glabrous (Fig. 2a and 2b). See Table 1 for an overview.

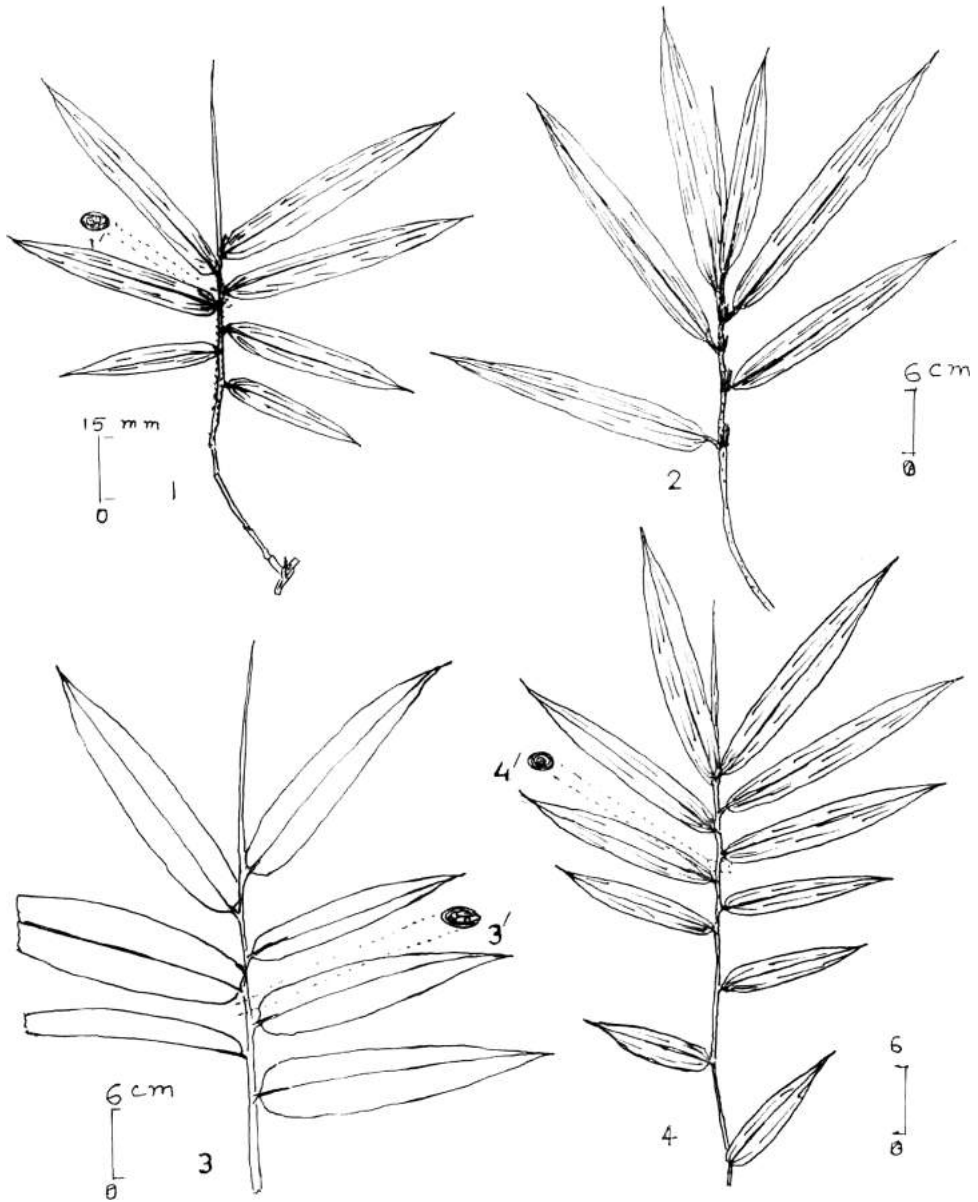


Figure 1. (1) Leaves of *Bambusa nutans*, (1') T.S. of branchlet 1. (2) Leaves of *Bambusa tulda*. (3) leaves of *Bambusa balcooa*, (3') T.S. of branchlet 3. (4) Leaves of *Bambusa bambos*, (4') T.S. of branchlet 4.

Bambusa tulda Roxb.

Assamese name Jati Bah.

A medium sized bamboo. At maturity, culms up to 24 m high, 28 cm in diameter, internodes up to 48 cm long. The number of culms in a clump is up to 80.

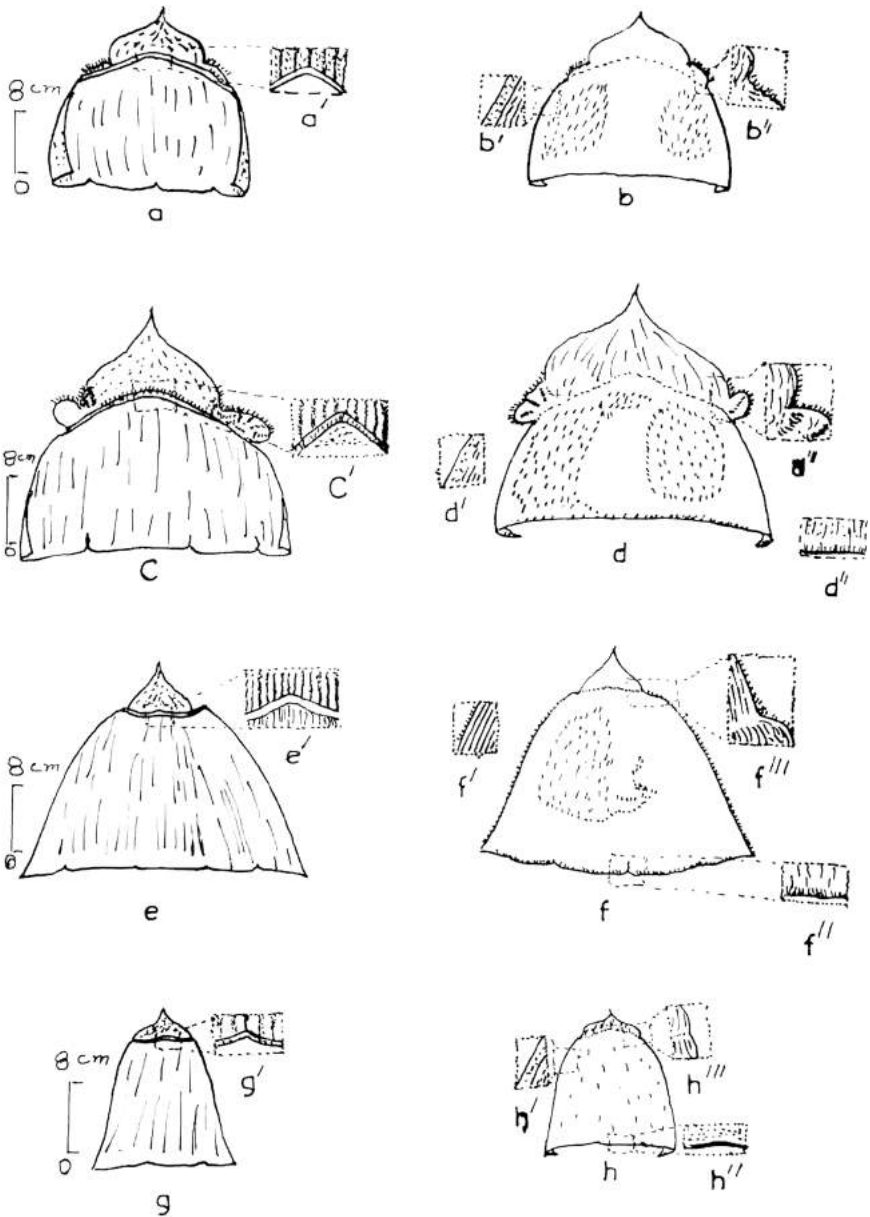


Figure 2. (a) Culm sheath of *Bambusa nutans* (adaxial surface), (a') enlarged part of (a). (b) Culm sheath of *Bambusa nutans* (abaxial surface), (b', b'') enlarged parts of (b). (c) Culm sheath of *Bambusa tulda* (adaxial surface), (c') enlarged part of (c). (d) Culm sheath of *Bambusa tulda* (abaxial surface), (d', d'') enlarged parts of (d). (e) Culm sheath of *Bambusa balcooa* (adaxial surface), (e') enlarged part of (e). (f) Culm sheath of *Bambusa balcooa* (abaxial surface), (f', f'', f''') enlarged parts of (f). (g) Culm sheath of *Bambusa bambos* (adaxial surface), (g') enlarged part of (g). (h) Culm sheath of *Bambusa bambos* (abaxial surface), (h', h'', h''') enlarged parts of (h).

Table 1.Overview of observations of *B. nutans* Wall ex. Munro

Authors	Others
Culm sheath: adaxial surface glabrous or sparsely glandular hairy, abaxial surface provided with dense appressed dark brown hairs in two sides but not in middle, abaxial surface of sheath base with thick wooly black or brown hairs. Ligule 1.5–2 mm, coriaceous, margin more or less in equal position, median region gradually upwards, smooth, round. Auricles 2, attached to ligule, unequal, one longer than the other and with long bristles, both auricles having wrinkles. In the adaxial surface of blade, long black or brown hairs seen in stripes, abaxial surface glabrous.	Culm sheath with appressed scattered black hairs on the back, base with soft deciduous hairs, ligule <i>ca.</i> 2 mm, entire to dentate; auricles 2, at the top of the sheath, large, wavy, unequal in size, one erect and the other decurrent, both fringed, with long curved bristles; adaxial surface clothed with appressed brownish blackish hairs [1]. Strongly cupped culm sheath blades, sheath covered with appressed black hairs on the back, base with soft deciduous hairs. Culm sheath interior has lines of dark hairs. Auricles broad wavy, one usually erect, the other decurrent, densely covered with long curved reddish bristles. Ligule 2–5 mm tall, margin finely serrated [2].

Leaf: about 10–14 leaves in each branchlet, 10–25 cm long and 2.3–3.5 cm wide at middle, linear-lanceolate, base obtuse, apex acuminate; glaucous green in dorsal surface, ventral surface whitish to light green. Dorsal surface glabrous except on veins, ventral surface puberulose, margin minutely dented, midvein yellow up to middle of lamina. Leaf sheath light brownish-yellow to green, glabrous, margin yellow, rest light green, gradually oval shaped towards upper portion and almost flat in the uppermost leaf sheath. Petiole short, *ca.* 2 mm long, yellow. Ligule *ca.* 2 mm long at middle, margin more or less equal, slightly lobed with minute cilia, whole body scabrous. Auricle small.

T.S. of branchlet oval-shaped (Fig. 1, panel 2).

Culm sheath: Wide triangular with pointed tip, 24–30 cm long and 28–32 cm wide, adaxial surface more or less glabrous except blade and auricle region, abaxial surface white powdery with patches of appressed brown hairs. Sheath tips more or less obtuse or slightly cordate, margins glabrous in both sides, hyaline and filmy. The base of the sheath wooly pubescence, basal region in equal positions, abaxial surface in the basal region provided with very minute hairs. The adaxial surface provided with two types of hairs: (a) long black hairs sparsely distributed in the lower region or near the ligule and (b) very fine yellow hairs in stripes forming row from base towards tip. Ligule coriaceous, small, continuous with the sheath top, margin in equal position. Auricle distinct, different in both sides, one small, tips rounded with long and hairy margin, the other broad, wider than long, with hairy margin, both auricles having wrinkled regions, waved with black, thick hairs in the adaxial surfaces and sparsely hairy in abaxial surfaces (Fig. 2c and 2d). See Table 2 for an overview.

Table 2.Overview of observations of *B. tulda* Roxb.

Authors	Others
<p>Culm sheath: adaxial surface more or less glabrous, except blade and auricle region, abaxial surface white powdery with patches of appressed brown hairs. The base of the sheath wooly pubescence, basal region in equal positions, abaxial surface in the basal region provided with very minute hairs. The adaxial surface provided with two types of hairs: (a) long black hairs sparsely distributed in the lower region or near the ligule and (b) very fine yellow hairs in stripes forming row from base towards tip. Ligule coriaceous, small, continuous with the sheath top, margin in equal position. Auricle distinct, different in both sides, one small, the other broad, wider than long, with hairy margin, both auricles having wrinkled regions, waved with black, thick hairs in the adaxial surfaces and sparsely hairy in abaxial surfaces.</p>	<p>Adaxial surface smooth and often with whitish powder, abaxial surface sometimes covered with appressed brown hairs; blade hairy within; ligule continuous with the sheath top, entire; auricles 2, unequal [1].</p> <p>Adaxial surface smooth and often whitish powdered, abaxial surface sometimes covered with appressed brown hairs. Blade hairy within, not strongly cupped and sometimes more persistent. Ligule 1–3 mm tall, continuous with the sheath top, margin finely serrated or entire. Auricles 2, broad and long, unequal, larger more prominent, one continuous with the blade and rounded with ciliate margin [2].</p>

Bambusa balcooa Roxb.

Assamese name Bholuka Bah.

A tall caespitose bamboo. Culms up to 29 m high, 10 cm in diameter; thick walled, internode up to 25 cm long. The number of culms per clump is up to 90.

Leaf: usually 6 leaves on each branchlet at any time, when there is 5, the other is in growing condition, 12–20 cm long, *ca.* 4 cm wide, oblong-ovate-lanceolate, apex acute-acuminate, base subcordate, tips pale-greenish-purple, margin rough, adaxial surface glabrous, glazy with distinct deep midvein, abaxial surface puberulose. Sheath brownish-yellow to green, provided with long silvery hairs in early stage. Petiole up to 3.3 mm long. Rachis/stem encircling by the leaf sheath more or less rounded. Ligule *ca.* 2 mm long, upper margin wavy, cilia short. Auricle very short (Fig. 1, panel 3).

Culm sheath: Wide triangular with pointed tip, *ca.* 23 cm long, 31 cm wide at the base, adaxial surface glabrous, glazy except the blade, abaxial surface with dense appressed dark brown hairs at the middle, tips more or less rounded with wide cordate apex, median region cordate, margin with long cilia, completely covered in one side, but only in the upper half of the other, the glabrous region of margin is hyaline. Ligule 4–7 mm high, coriaceous, in equal position, upper margin slightly undulate with very fine cilia. Auricle indistinct, not extended but the region with black hairs. Blade triangular *ca.* 4 cm long, 6 cm broad with pointed acute tip. Blade, on the adaxial surface, having two types of hairs: (a) long black or brown hairs sparsely distributed all over the body and (b) very fine yellow or colourless

Table 3.Overview of observations of *B. balcooa* Roxb.

Authors	Others
Culm sheath: abaxial surface with dense appressed dark brown hairs at the middle, tips more or less rounded with wide cordate apex, median region cordate, margin with long cilia, completely covered in one side, but only in the upper half of the other. Ligule 4–7 mm high, coriaceous, in equal position, upper margin slightly undulate with very fine cilia. Auricle indistinct. Blade, on the adaxial surface, having two types of hairs: (a) long black or brown hairs sparsely distributed all over the body and (b) very fine yellow or colourless hairs in stripes forming row from top to bottom; blade glabrous on the abaxial surface.	Adaxial surface glabrous, abaxial surface with densely appressed dark brown hairs, margin ciliate; lower ones much shorter and broader than upper ones. Ligule 5–8 mm high, denticulate, membranous; auricles absent or very small ciliate [1]. Culm sheaths on the lower nodes (from the base to mid-culms) short and broad, densely appressed- hairy on the upper surface. The lower side of the blade edge wavy, auricle very short or absent [2].

hairs in stripes forming row from top to bottom; blade glabrous on the abaxial surface (Fig. 2e and 2f). See Table 3 for an overview.

Bambusa bambos Voss.

Assamese name Kotoha Bah.

Densely tufted, spiny bamboo. At maturity, culms up to 20 m high, 30 cm in diameter; thick walled, internodes up to 21 cm long. The number of culms per clump is up to 80.

Leaf: usually 8 leaves on each branchlet at any time, when there is 7 or less, the others are in growing condition, 12–18 cm long and 1.4–1.8 cm broad, ovate-lanceolate, apex acuminate, tip pale greenish purple, base obtuse, dark green, shortly petioled, petiole up to 2 mm long, adaxial surface glabrous, glazy with distinct deep midvein up to middle, abaxial surface puberulose, margin rough. Ligule short, *ca.* 1 mm long, upper margin more or less straight, cilia short. Auricle very short, with few, 4–5 mm long bristles. Leaf sheath light brownish-yellow to green, provided with long silvery hairs.

Rachis/stems encircling by the leaf sheaths more or less rounded (Fig. 1, panel 4).

Culm sheath: wide triangular with pointed tip, 16–18 cm long and 16–18 cm broad, adaxial surface glabrous or sparsely minutely hairy in stripes, abaxial surface glabrous, margins glabrous, hyaline, filmy, in median region of sheath upper margin slightly upwards. Ligule coriaceous, small, margin in equal position. Auricle indistinct from ligule (Fig. 2g and 2h). See Table 4 for an overview.

Bambusa pallida Munro

Assamese name Bijuli Bah.

Table 4.Overview of observations of *B. bambos* Voss.

Authors	Others
Culm sheath: wide triangular with pointed tip, adaxial surface glabrous or sparsely minutely hairy in stripes, abaxial surface glabrous, margins glabrous, hyaline, filmy, in median region of sheath upper margin slightly upwards. Ligule coriaceous, small, margin in equal position. Auricle indistinct from ligule.	Culm sheaths coriaceous, glabrous to pubescent with dark brown velvety hairs [1]. Culm sheath usually Coriaceous, glabrous to pubescent with dark-brown hairs, deciduous at the time the branches develop; ligule continuous with sheath top; margin fringed with cilia; auricle inconspicuous [3].

A caespitose bamboo, growing in thick clumps. At maturity, culms up to 18 m high, 13 cm in diameter, covered with white powder, internodes up to 30 cm long. The number of culms per clump is up to 60.

Leaf: usually 6–8 leaves in a branchlet at maturity, 18–26 cm long and 2.2–2.8 cm broad, linear or oblong-obovate, light green above and whitish green beneath, forms powdery appearance, upper surface finely scabrous, lower surface finely hirsute, margin scabrous, base more or less obtuse, oblique, petiole short, *ca.* 2 mm long, yellow. Leaf-sheath yellowish-green, glabrous. Auricle extended with long bristles, bristles 7–8 mm long. Ligule short, *ca.* 1–1.5 mm long, upper margin straight, basal region rounded. Leaf sheath with stem round at basal region and gradually become oval towards apex (Fig. 3, panel 5).

Culm sheath: Wide triangular with pointed tip, 16–20 cm long, 12–14 cm wide at base, margin glabrous, hyaline and filmy, tip more or less obtuse, blade triangular and glabrous, both surfaces with fine ridges from top to bottom, adaxial surface glabrous with whitish powdery patches distributed throughout, abaxial surface glabrous, muricate. Median region finely obtuse. Ligule coriaceous, small, margin not in equal position, right margin slightly in lower level than the left. Auricle distinct, rounded, left one small and long; right one short and wide, with long black hairs (Fig. 4i and 4j). See Table 5 for an overview.

Melocanna baccifera (Roxb.) Kurz

Assamese name Tarai/Muli Bah.

A diffuse clumped, thin walled evergreen bamboo. At maturity, culms up to 20 m high, 7 cm in diameter, internodes up to 50 cm long.

Leaf: usually 6–8 leaves at any time on each branchlet, 24–26 cm long and 2.5–3 cm wide, oblong-ovate lanceolate, pale green, apex acute-acuminate, base obtuse., margin rough, adaxial surface glabrous, glazy with distinct deep midvein up to middle, abaxial surface puberulose. Petiole *ca.* 6–9 mm long. Leaf sheath light brownish-yellow to green, glabrous. Ligule short, *ca.* 1–1.2 mm long; upper margin more or less straight. Auricle having long white bristles (Fig. 3, panel 6).

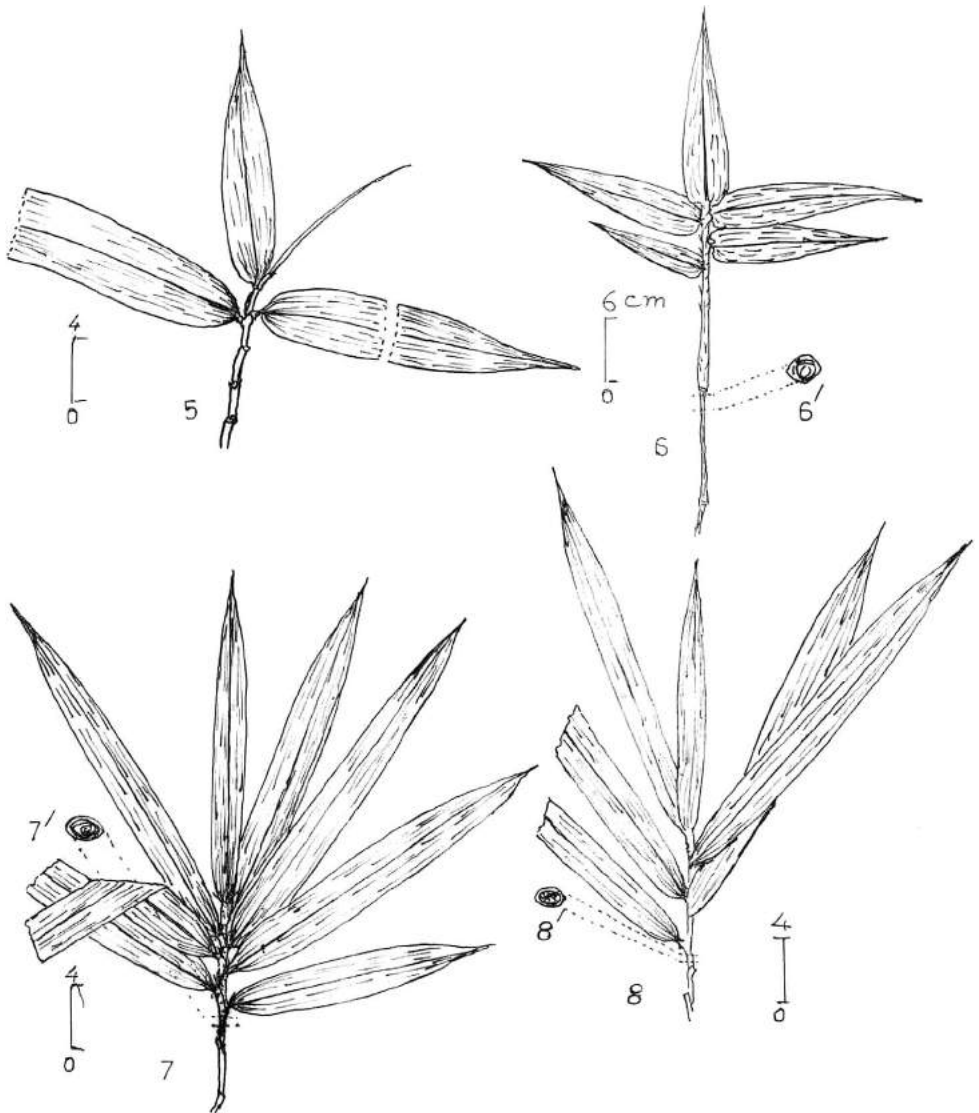


Figure 3. (5) Leaves of *Bambusa pallida*. (6) Leaves of *Melocanna baccifera*, (6') T.S. of branchlet 6. (7) Leaves of *Dendrocalamus hamiltonii*, (7') T.S. of branchlet 7. (8) Leaves of *Dendrocalamus giganteus*, (8') T.S. of branchlet 8.

Culm sheath: Conical with long narrow aristed tip, ca. 15–20 cm long and 14–20 cm wide at base, adaxial surface glazy, glabrous, tip long narrow, aristed, median region of sheath deep concave, margin glabrous, hyaline and filmy. Both surfaces of the sheath are more or less glabrous. Ligule very short, coriaceous, margin toothed, more or less in equal position, median region depressed like bowl, smooth. Auricle attached to ligule, equal, conspicuous, more or less glabrous in both surfaces. Blade

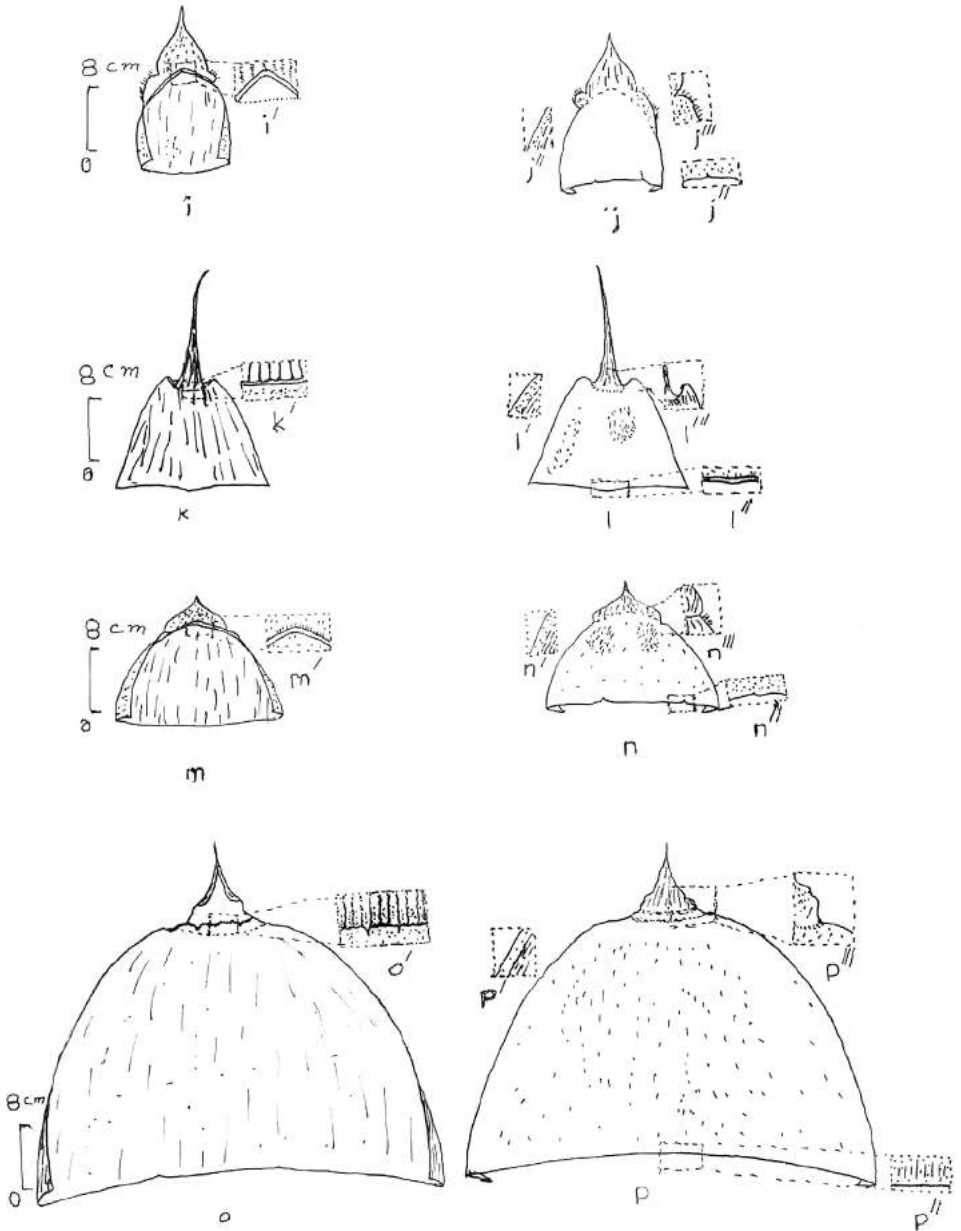


Figure 4. (i) Culm sheath of *Bambusa pallida* (adaxial surface), (i') enlarged part of (i). (j) Culm sheath of *Bambusa pallida* (abaxial surface), (j', j'', j''') enlarged parts of (j). (k) Culm sheath of *Melocanna baccifera* (adaxial surface), (k') enlarged part of (k). (l) Culm sheath of *Melocanna baccifera* (abaxial surface), (l', l'', l''') enlarged parts of (l). (m) Culm sheath of *Dendrocalamus hamiltonii* (adaxial surface), (m') enlarged part of (m). (n) Culm sheath of *Dendrocalamus hamiltonii* (abaxial surface), (n', n'', n''') enlarged parts of (n). (o) Culm sheath of *Dendrocalamus giganteus* (adaxial surface), (o') enlarged part of (o). (p) Culm sheath of *Dendrocalamus giganteus* (abaxial surface), (p', p'', p''') enlarged parts of (p).

Table 5.Overview of observations of *B. pallida* Munro

Authors	Others
Culm sheath: blade triangular and glabrous, both surfaces with fine ridges from top to bottom, adaxial surface glabrous with whitish powdery patches distributed throughout, abaxial surface glabrous, muricate. Ligule coriaceous, small, margin not in equal position, right margin slightly in lower level than the left. Auricle distinct, rounded, left one small and long; right one short and wide, with long black hairs.	Culm sheath base covered with appressed white hairs; abaxial surface appressed black hairy, adaxial surface glabrous or sparsely hairy; ligule very short; auricle quite small, rounded, with bristles, blades at first greenish, changing to straw colour within few days [1].

Table 6.Overview of observations of *M. baccifera* (Roxb.) Kurz

Authors	Others
Culm sheath: conical with long narrow aristed tip, ca. 15–20 cm long and 14–20 cm wide at base, adaxial surface glazy, glabrous, tip long narrow, aristed, median region of sheath deep concave, margin glabrous, hyaline and filmy. Both surfaces of the sheath are more or less glabrous. Ligule very short, coriaceous, margin toothed, more or less in equal position, median region depressed like bowl, smooth. Auricle attached to ligule, equal, conspicuous, more or less glabrous in both surfaces. In the adaxial surface of blade, very fine hairs seen in stripes, abaxial surface glabrous.	Culm sheath brittle, glabrous or sparsely with whitish appressed hairs on the back. Ligule very short with undulated or toothed margin, auricles small, sub-equal, membranous, fringed with silvery bristles [1]. Fairly large, yellowish-brown, brittle, felted; symmetric, narrow; auricle prominent, blade arising from a concave depression. Culm sheaths covered with white hairs at first, ridge present on the outside of the sheath where the blade is attached, blade narrow, sword-shaped and longer than sheath. Ligule serrate, 1–2 mm tall [2].

long narrow with arrested tip. In the adaxial surface of blade, very fine hairs seen in stripes, abaxial surface glabrous (Fig. 4k and 4l). See Table 6 for an overview.

Dendrocalamus hamiltonii Nees and Arn. ex Munro

Assamese name Kakoh/Pecha Bah.

A large caespitose bamboo, often curved downwards. At maturity, culms up to 24 m high, 29 cm in diameter, internodes up to 31 cm long. The number of culms in a clump is up to 50.

Leaf: usually 13–17 leaves on each branchlet, ovate-lanceolate, 35–45 cm long and 10 cm wide, palet green, apex acute or acuminate, base cordate to subcordate, usually 8–12 veinlets on both sides of midvein. Leaf sheath light brownish-yellow to light green. Petiole ca. 5 mm long, margin rough, adaxial surface glabrous, glazy

Table 7.Overview of observations on *D. hamiltonii* Nees and Arn. ex Munro

Authors	Others
Culm sheath: abaxial surface in the sheath body provided with two types of hairs: (a) long appressed brown hairs in the upper region of sheath and (b) short glandular hairs sparsely distributed all over the body. Adaxial surface sparsely glandular hairy all over the body. Ligule very small, coriaceous, margin in equal position. Auricle indistinct.	Culm sheath long and stiff, variable in size, glabrous, shining within, rough and glabrous or with scanty patches of stiff brown hairs on outer side. Ligule smooth, entire [1]. Long and stiff, variable size, shining within, rough with scanty patches of stiff brown hairs on outer side. Auricles acute. Ligule smooth, entire [2].

with distinct deep midvein up to middle, abaxial surface puberulose. Leaf sheath glabrous. Ligule 3.5–4 mm long, upper margin wavy. Auricle very short (Fig. 3, panel 7).

Culm sheath: wide triangular with pointed tip, 15–17 cm long and 20–23 cm wide, tip straight to cordate, margins glabrous in both sides, hyaline and filmy. Abaxial surface in the sheath body provided with two types of hairs: (a) long appressed brown hairs in the upper region of sheath and (b) short glandular hairs sparsely distributed all over the body. Adaxial surface sparsely glandular hairy all over the body. Median region straight to obtuse. Ligule very small, coriaceous, margin in equal position. Auricle indistinct (Fig. 4m and 4n). See Table 7 for an overview.

Dendrocalamus giganteus Munro

Assamese name Gadhoi Bah.

Tallest bamboo with closed culms. At maturity, culms up to 32 m high, 28 cm in diameter, internodes up to 40 cm long. The number of culms in a clump is up to 50.

Leaf: usually 10–12 leaves on each branchlet, oblong-elliptic, 50–55 cm long and 6–12 cm wide, shining, light green, apex acute, pointed, base ovate rounded, margin finely toothed, adaxial surface glabrous, glazy with distinct deep midvein up to middle, abaxial surface finely scabrous, sheath glabrous, petiole short, *ca.* 3–5 mm long. Ligule *ca.* 3–4 mm long, upper margin undulate. Auricle very short or inconspicuous. Petiole short, *ca.* 3–5 mm long (Fig. 3, panel 8).

Culm sheath: Wide triangular with pointed tip, 42–45 cm long and 50–55 cm wide at base, margin glabrous, hyaline. Adaxial surface glazy with numerous small glandular hairs all over the body, abaxial surface with thinly appressed light brown hairs in the middle, lower portion of the sheath covered with minute black glandular hairs. Sheath tip cretaceous, darker than the sheath, margin in equal position and upper margin with teeth-like extensions, undulate. Blade triangular, 9–10 cm long, 5–6 cm wide with pointed acute tip. Blade, on the adaxial surface having two types of hairs: (a) long black or brown hairs sparsely distributed all over the body, (b) very fine yellow or colourless hairs in stripes forming row from top to bottom. Blade with

Table 8.Overview of observations of *D. giganteus* Munro

Authors	Others
Culm sheath: adaxial surface glazy with numerous small glandular hairs all over the body, abaxial surface with thinly appressed light brown hairs in the middle, lower portion of the sheath covered with minute black glandular hairs. Blade, on the adaxial surface having two types of hairs: (a) long black or brown hairs sparsely distributed all over the body, (b) very fine yellow or colourless hairs in stripes forming row from top to bottom. Blade with glandular hairs in the abaxial surface, sparsely distributed in upper region while densely distributed in the basal region.	Culm sheaths: Hard, smooth, shining within, dull yellow and covered with dark brown hairs on the back; ligule 8–13 mm high, stiff, dark, serrate; auricles prominent, brown, crisped [1].
Ligule with serrate median region, 9–15 mm long.	Very large, hard, glabrous and shining within, colour dull yellow, very thinly covered with golden stiff hairs. Ligule tall 8–12 mm, serrate, stiff. Auricles prominent, brown [2].
Auricle inconspicuous or rarely conspicuous.	

glandular hairs in the abaxial surface, sparsely distributed in upper region while densely distributed in the basal region.

Ligule with serrate median region, 9–15 mm long. Auricle inconspicuous or rarely conspicuous (Fig. 4o and 4p). See Table 8 for an overview.

DISCUSSION

Culm sheath and leaf morphology has played a significant role in the identification of various species of bamboo. Earlier, a number of botanists classified bamboos based on their reproductive structures [4–13]. Amongst them are: Hooker, Munro, Brandis, Camus, Arber, Holtum and Hildebrand.

The drawback faced in this classical method of identifying bamboos by reproductive structures is the gregarious nature of flowering and the dying of clumps soon after flowering.

Other aspects to identify and classify bamboos are the study of morphological and anatomical characters of culms, culm sheaths and leaves.

Porterfield [14] studied the vascular anatomy of the leaf sheaths of some bamboos. Shigenmatsu [15] concentrated on analysing the stem form of some important Japanese bamboos. Metcalf [16] studied the anatomy of bamboo leaves. Ghosh and Negi [17] concentrated on the study of the epidermis of the culm of six species of bamboos. Raizada and Chatterjee [18] studied the morphology of the culm sheaths to identify different species of bamboos. Pattanath and Ramesh Rao [19] studied the epidermis and internodal structure of twelve species of bamboos, which can be used for identification of bamboos. Bahadur [20] developed a key for the

identification of bamboos based on culm buds and bud sheaths. Fujimoto [21] attempted a classification of Bambusoideae based on the leaf structure specially the ligule portion. Other important publications on bamboo taxonomy are that of McClure [22], Dransfield [23], Soderstrom [24], Soderstrom and Ellis [25], Tewari [25], Banik [25]. Most of taxonomic descriptions, including recent ones, are based on scanty herbarium specimens [1].

However, these characters were basically on the overall shape culm sheath only and sometimes the sheaths of different bamboo species look identical. Also, on the contrary, sometimes the same species may exhibit different characteristics with regard to size, shape etc. depending on site, climatic conditions, etc.

In the present investigation, it is found that the species can be easily distinguished from one another based on the characters like size and pubescence of culm sheath, auricle nature, ligule size including its shape at median region.

In the species presently studied, *D. giganteus* is easily distinguishable from the rest based on their much bigger size of culm sheath and serrate nature of ligule on upper margin. Likewise, *B. balcooa* is distinguishable from the rest for their cordate ligule base and ciliate on culm sheath margin. *B. bambos* is distinguishable by its glabrous abaxial, adaxial and margin of culm sheath, as well as indistinct ligule. *B. nutans* is characterized for its glabrous margin and sparsely ciliate at basal region of sheath. *B. pallida* is different from the rest in its unequal auricle and its shape i.e. wider than length. Likewise *B. tulda* is distinguishable by ciliate ligule and auricle, as well as acute ligule. *D. hamiltonii* is distinguishable from the rest for its wider culm sheath than length, median region of ligule straight to obtuse.

A key based on culm sheath and leaf characters formulated to the species studied is given below.

KEY TO THE SPECIES BASED ON CULM SHEATH CHARACTERS

1. Culm sheath blade much longer than wide, with long aristed or caudate tip
..... *Melocanna baccifera*
- 1'. Culm sheath blade wider or equal to length, blade tip acute or acuminate:
2. Culm sheath smaller, ca. 30 cm long, and 30–32 cm broad at base, ligule entire when present:
 3. Auricle conspicuous:
 4. Ligule margin more or less in equal position:
 5. Sheath 24–30 cm long, median region of ligule acute. . . *Bambusa tulda*
 - 5'. Sheath 18–20 cm long, median region of ligule obtuse/round
..... *Bambusa nutans*
 - 4'. Ligule margin in unequal position *Bambusa pallida*
- 3'. Auricle absent or if present indistinct:

6. Base of sheath bear dense wooly hairs, margin with long cilia
 *Bambusa balcooa*
- 6'. Base as well as margin of sheath glabrous:
7. Sheath width equal or longer than length, hairs sparsely distributed
 as well as in stripes in the adaxial surface of blade, dense appressed
 brown hairs absent in the abaxial surface of sheath
 *Bambusa bambos*
- 7'. Sheath wider than length, hairs sparsely distributed in the adaxial
 surface of blade, dense appressed brown hairs present in the abaxial
 surface of sheath.
 *Dendrocalamus hamiltonii*
- 2'. Culm sheath much bigger, 40–45 cm long and 50–55 cm wide at base, ligule
 with serrate median region *Dendrocalamus giganteus*

KEY TO THE SPECIES BASED ON LEAF CHARACTERS

1. Auricle bristled:
2. Leaf-sheath with fine long silvery hairs
3. Leaf-sheath with fine stagy soft hairs *Bambusa nutans*
- 3'. Leaf-sheath with long silvery hairs *Bambusa bambos*
- 2'. Leaf-sheath more or less glabrous:
4. Lower surface of the lamina powdery white petiole short, max. 2 mm
 long *Bambusa pallida*
- 4'. Lower surface of the lamina light green in colour; petiole long, 7–9 mm
 long *Melocanna baccifera*
- 1'. Auricle not bristled
5. Leaf-sheath having long silvery hairs *Bambusa balcooa*
- 5'. Leaf-sheath glabrous:
6. Lamina dark green in colour; lower surface with fine velvety whitish
 hairs *Bambusa tulda*
- 6'. Lamina light green in colour; lower surface more or less glabrous:
7. Lamina smaller, max. length 45 cm and breadth 6–10 cm at middle
 *Dendrocalamus hamiltonii*
- 7'. Lamina much bigger, max. length 50–55 cm and breadth 6–12 cm at
 middle *Dendrocalamus giganteus*

Acknowledgements

The authors are highly thankful to the Director, Rain Forest Research Institute, Jorhat for his encouragement and valuable suggestions in preparing the paper.

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